Software Agents and Multi-Agent Systems

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What is a Software Agent?

Autonomous & Persistent: The main point about agents is that they are capable of acting independently, exhibiting control over their internal state.

Trivial (non-interesting) agents:

- Software thermostats, UNIX daemons (e.g. biff)

An intelligent agent is a persistent computer system capable of flexible autonomous action in some environment.

"flexible" means

- Reactive (expect change, failure)
- Pro-active (achieve goals via multiple means)
- Social (multi-agent systems)
Example: Deep Space One

Deep Space 1's Incredible Ions
12 Astounding Technologies

Does Deep Space 1 have a mind of its own?
Initial Image taken by Spacecraft

Onboard Image Processing & Feature/Cloud Detection

Image New Target

Retarget for New Observation Goals

Onboard Replanning
Multi-Agent Systems

- Natural problem distributions
- Concurrent speedups
- Increased reliability/robustness
- Bounded/Limited rationality
- Human organizational contexts
Hospital Scheduling

Nursing Unit 1
- Barium
- X-Ray
- min
- min
- min
- min
- min

Nursing Unit 2
- Draw Blood
- Test
- min
- min
- min
- min
- min

Ancillary 1
- type
- min
- task with quality accrual function
- min
- task already communicated to ancillary

Ancillary 2
- min
- subtask relationship
- enables relationship

Ancillary 3
- min
- requires delay
- inhibits

Physical Therapy
Distributed Computing vs. Distributed AI Viewpoints

- Distributed Computing
  - Tightly coupled, parallelization, centralized control
  - [Distributed OS] Independent processes, load balancing
  - Total database consistency
- Distributed AI
  - Loose coupling, distributed control
  - Interdependent processes
  - “Functionally Accurate” (often inconsistent)
Key Drivers for Agents [Jennings]

- Open Systems
  - Entities not known in advance and can freely enter and leave system at run time (e.g. Internet)
- Complex Distributed Systems
  - Industrial-strength software is difficult to build, even with modern software engineering advances
  - Agent concept is a new abstraction for system builders
- Ubiquitous systems
  - Presently, too much onus on user, not computer
  - Make it more of an equal partnership
  - Machine should not just be a dumb receptor of tasks
  - “future of computing will be 100% driven by delegating to, rather than manipulating, computers” (Negroponte 1995)
Designing Intelligent Agents & Organizations that:

- Operate in environments with uncertainty, deadlines
- Have multiple, possibly +/- interacting goals/objectives
- Need to satisfice, not optimize
  - produce results that vary in quality depending on time pressure
- Interact with other agents
  - non-independent subproblems
  - partially overlapping goals/objectives
Research Agenda

» Representing and reasoning about these environmental features
  » Distributed Planning & Scheduling (TAEMS) [Gang]
  » Multi-agent Coordination (GPGP) [Wei]
» Software agent architectures and organizations that embody these solutions, that adapt in dynamic environments
  » DECAF (earlier, RETISINA)
» Information Gathering Systems based on agent models
  » Bioinformatics [Gang, Kay, Li, Sachin, Morgan]
  » Text integration [Terry]
» Understanding human organizational models computationally
  » Economically-orientated Organizational Behavior [Foster]
  » Organization Formation [Sachin]
» Organizational Policy interaction
Coordinating Computational Actions

- Primary difficulties in CHOOSING and TEMPORALLY ORDERING actions
  - incomplete view of the problem
  - dynamically changing situation
  - uncertainty in the outcomes of actions
- Overcome difficulties with Coordination Mechanisms
  - schedules, plans, timelines, appointments, commitments
  - laws, rules, social behavioral norms
  - organizations, roles, negotiated order
TÆMS Task Structure Representation

- Representing complex domains
  - worth-oriented
  - time-oriented
  - distributed
  - uncertain

- Representing quantitative change in characteristics over which agents have preferences
  - quality
  - cost
  - duration vs. deadline

- State-based semantics

- Annotation for HTN style task networks
A Vision for Multi-Agent System Engineering

DECAF: Distributed, Environment Centered Agent Framework

- Focus on programming agents, not designing internal architecture
- Programming at the multi-agent level
- Value-added architecture
- Support for persistent, flexible, robust actions
DECAFE Architecture

- Plan file
- Incoming KQML/FIPA messages
- Incoming Message Queue
- Objectives Queue
- Task Queue
- Agenda Queue
- Task Templates Hash Table
- Pending Action Queue
- Action Results Queue
- Agent Initialization
- Dispatcher
- Planner
- Scheduler
- Executor
- Domain Facts and Beliefs
- Outgoing KQML/FIPA messages
- Action Modules

[concurrent]
Task Structure [TÆMS]

- Multiple ways of achieving goal
  - And, Or, Sum, Xor
  - Schedule/execution time decision (not plan-time)
- Multiple outcomes can enable different downstream actions (contingencies, loops)
- Explicit representation of non-local tasks
Basic BioMAS

**Domain-Independent Task Agents**
- Sequence Addition Applet
- User Query Applet
- Proxy Agent
- Annotation Agent
- Sequence Source Processing Agent
- GenBank Info Extraction Agent
- SwissProt/ProSite Info Extraction Agent
- ProDomain Info Extraction Agent
- Psort Analysis Wrapper

**Task Agents**
- Matchmaker Agent
- Agent Name Server Agent
- Local Knowledgebase Management Agent

**Interface Agents**
- RETSINA-style Multi-Agent Organization

**Information Extraction Agents**
GoFigure!
a functional annotation tool using Gene Ontology

GoFigure
This form allows you to query your DNA or protein sequence against the GO annotated sequences from GO Consortium members' databases. If you wish to use this facility during a course, or if you have any problems or suggestions, then please contact us at info@cis.udel.edu

1. Input Sequence
Please enter your DNA or protein sequence (in FASTA format) into the text box below. For more information on the FASTA format, please click here.

- DNA sequence (blast)
- protein sequence (blastp)

Enter or cut and paste sequence here:

2. Choose Ontologies
Select the ontologies for which you would like the GoFigure displayed.

- Molecular Function
- Biological Process
- Cellular Component

3. Choose Weight Coefficients
In addition to the GoFigure graph, you can specify weight coefficients for factors such as e-value and evidence code, which are input to produce the GoDel automated annotation.

E-value × Evidence = 1

4. Email Address
You must enter your email address in the box below to use this service. Email addresses in the standard form, i.e. user@udel.edu.

Email address >>

5. Finish!
To run your query, click the 'Submit Job' button. The 'Reset Form' button acts as you might expect!
Summary

- Agent Research is fun, exciting, cutting-edge
- Still very young field
  - open, multi-disciplinary
- Our foci:
  - Coordination, planning, scheduling
  - Agent toolkits
  - Information Gathering
  - Organizational Issues